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Radionuclide Characterization of Subsurface Soil on the Site of Building 3505 at Oak Ridge National Laboratory

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RADIONUCLIDE CHARACTERIZATION OF SUBSURFACE SOIL ON THE SITE OF BUILDING 3505 AT OAK RIDGE NATIONAL LABORATORY

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ABSTRACT

The Metal Recovery Facility, Building 3505, was operated by the staff of Oak Ridge National Laboratory (ORNL) as a pilot and small-scale-production nuclear fuel reprocessing plant from 1952 until 1960. Because further use of this facility is not anticipated, decontamination and decommissioning (D & D) of this facility and site is planned as part of the ORNL D & D program.

This report is a review of the radiological contamination characterization of subsurface soil surrounding the 3505 facility. In order to determine the environmental radiological soil conditions, ninety-two samples at varying depths were collected from 25 cores. Sample tubes were driven into the ground and segments of soil cores were retrieved at depths from the ground surface to subsurface consolidated material.

Forty samples of the 92 collected had detectable gamma activities [i.e., $>2\times10^{-2}$ Bq/g (0.5 pCi/g)] of ^{137}Cs. However, only four samples, all from the same borehole, were found to have significant amounts of ^{137}Cs with a maximum of 1.7×10^{3} Bq/g (4.6×10^{4} pCi/g). These four samples also contained the highest activities of other radionuclides (^{60}Co, ^{90}Sr, ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Am). These subsamples came from core number 4DD, which was the deepest core collected. Core 4DD was taken at the southwest corner of the site, which is at the lower elevation of the site. Since most of the activity in this core was found below the bedrock (or shale) in the groundwater region, the contamination is probably not from Building 3505. Additional investigation in the area around core location 4DD will be required to determine the extent of contamination.

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I. INTRODUCTION

Building 3505, the Metal Recovery Facility or Fission Product Development Laboratory Annex is located on Third Street to the south of Central Avenue in the main ORNL Plant area (Fig. 1). This building was in operation from 1952 to 1960 as a nuclear fuel reprocessing plant. During its eight-year operation, 320,662 kg of Uranium, 184 kg of Plutonium, 1,344 kg of Neptunium, and 55 kg of Americium were isolated (UCC-ND Engineering, 1980).

This facility is a two-story building with an approximately 15.3 m (50.3 ft) long, 1.9 m (6.3 ft) wide, and 4.2 m (13.9 ft) deep canal at the northwest end. Two 8517-liter (2250-gallon) cylinderical stainless steel tanks, set in a concrete slab, were buried vertically about 15 m (50 ft) away from the southeast end of the building (Fig. 2). Nuclear fuel was processed in cells A through G and fission products were discarded from cells A and B through underground pipelines to radioactive storage tanks W-19 and W-20. (Fig. 2). Before the subsurface investigation, a radiological survey of Building 3505 and the surrounding area was completed (Boing, 1981). It was found that the building was contamination-free except for locations of past spills which have all been well surveyed and are reviewed in Boing, 1981. The water-filled canal was used as a radiation-shield during the handling of irradiated fuel elements. The waste tanks were used to store fission products from Building 3505 prior to transfer to the Fission Product Development Laboratory, located in Building 3517.

From the past function of the facility, high radioactivity from the fission products was to be expected in the canal, in Cells A and B, in the waste processing pipelines, in tanks W-19 and W-20, and in those pipelines that were used to transfer fission product waste from tanks W-19 and W-20 to Building 3517. Cells C through G could also be potential areas for uranium and transuranium contamination (UCC-ND Engineering, 1980, Boing, 1981).

Building 3505 was abandoned in 1960. Thus, many short-lived radioactive elements have decayed to nondetectable levels. However, a recent survey (Boing, 1981) indicates that this facility has widespread residual fission products, ^{137}Cs and ^{90}Sr, and uranic and transuranic nuclides (U, Pu, Np, and Am) contamination. It has been determined (UCC-ND Engineering,

1980, Boing, 1981) that this facility poses a high degree of hazard for the plant employees and for the environment. This determination was based on the contamination levels, the building structure deterioration, and its location among other active ORNL facilities. Thus, Building 3505 has been identified as one of the early decontamination and decommissioning (D & D) projects at ORNL.

The overall approach to this project is (1) to identify any hazardous material on the site, such as the building structure, machines, instruments, tanks, soil, etc., (2) to categorize the degree of contamination [e.g., in order to package and to dispose of the materials in compliance with DOE guides (DOE Order 5480, DOE Order 5820)], and (3) to restore the entire site to a usable condition.

Evaluation Research Corporation (ERC) completed a survey of all accessible surfaces of the facility, which included the entire building structure, all the internal equipment and instruments, and the surrounding surface soil (Boing, 1981). In the present study, only radionuclide contamination of the subsurface soil surrounding the facility has been investigated.

In order to determine the types and degree of contamination and its distribution, soil samples were collected at different locations, with emphasis on suspicious areas. The drilling was done by Rust Engineering Corporation with supervision from the staff of the UCC-ND Engineering Division. Soil samples were processed by members of the Department of Environmental Management (DEM) of the IS&AHP Division.

2. PROCEDURE

2.1 SOIL CORE LOCATION

A survey plan, provided by ERC for subsurface sampling (ERC, 1979) was used for the identification of the core locations. A grid layout applying a numerical scale horizontally and an alphabetical scale vertically (Fig. 3) created a fast core mapping system. Each cell was identified by a number followed by a letter.

Originally, 40 cores of 7.6-cm (3-in.) diameter were planned by ERC. Twenty cores were to be taken at a depth of 1.52 m (5 ft), ten at 3.03 m

(10 ft), and ten at 6.06 m (20 ft). The cores were to be taken approximately every ten meters on the grid (Fig. 3). Piping and conduit locations were identified from drawings of the surrounding area and used in establishing sampling locations. In some cases, coring at the exact grid coordinates was impossible due to the location of the piping and conduit lines. In these cases, cores were taken in the next closest grid block. Cores in grid blocks 20J, 33J, and 59V were chosen because they were close to pipes exiting from the building.

The plot plan for Building 3505 indicated general drainage from the north side to the southwest corner of the site. Thus an extra core 4DD, was scheduled to be taken (Fig. 3). All other locations for coring were selected on a random basis using the 10 m grid. The actual sites are shown in Figure 4. The results of the analyses of surface soil reported by ERC (Boing, 1981) were used to make minor adjustments on the grid locations chosen for subsurface samples. Due to practical reasons, fifteen cores were not drilled as planned and four extra cores were drilled. Of these fifteen, six cores (1A, 9A, 20A, 29A, 39A, and 49A) were deleted because they were scheduled to be drilled in the area of the gunite tanks. Five cores (20J, 33J, 25Q, 44P, and 34Z) were deleted because they were scheduled to be angle drilled, and an additional four cores (10P, 14DD, 39DD, and 49DD) were deleted for other reasons. Four extra cores (1AA, 20G, 49G, and 47P) were drilled to supplement those deleted (Fig. 4).

The final core locations were further adjusted during actual drilling to avoid existing obstructions. A total of 29 cores were drilled . Four of the 29 (59A, 1M, 18O, and 1W) could only be drilled to a depth of 20 - 25 cm (8 to 10 in.). No soil samples from these cores were collected. There were only 25 cores from which soil samples were collected (Fig. 4).

2.2 METHOD OF SOIL SAMPLE COLLECTION

In this operation, a soil sampler 3.18 cm (1.25 in.) in diameter was used. Soil segments were collected by means of an auger and a coring tube (Fig. 5). The coring tube was mechanically driven into the soil and the core samples were extracted at 46 cm (18 in.) lengths (Fig. 6). Following the coring, a large diameter auger was used to enlarge the hole and provide a surface

for the next 46-cm sample. This process continued until the coring machine could not go any deeper. When consolidated material was encountered that prevented the corer from further penetration, the coring was halted.

The 46-cm segments were placed in sectioned wooden boxes and labeled with identification numbers and segment sequence numbers (Fig. 7). A member of the Health Physics Department surveyed the coring equipment to prevent cross-contamination, and the coring tube was cleaned after each segment was extracted. Each core segment was surveyed (Fig. 8) and radiation tags with proper readings were placed on each box. Cores were then taken to a low background area and scanned with a gamma scintillation probe.

2.3 PREPARATION OF SOIL SAMPLE

The 25 locations which were sampled resulted in a total of 81 core segments. When there was an apparent difference in the type of soil within one 46 cm length, it was divided into two segments. There were eleven 46-cm segments that contained two different types of soil composition. For these samples, a letter A or B was used after the core segment sequence number. This procedure resulted in a total of 92 soil samples for processing and analysis.

Each sample was oven dried at 105^{o}C (221^{o}F) for 8 hours, then crushed and ground to a fine mesh of 500μm or less. In order to reduce cross-contamination, the grinder was cleaned after each sample with a wire brush and air blower. Samples which had sufficient activity to be detectable with a G-M survey meter were ground by hand to prevent cross-contamination of other samples and grinding equipment.

The ground samples were thoroughly mixed, and a portion of this mixture was placed in a preweighed petri dish [7.0 cm (2.76 in.) diameter and 1.6 cm (0.63 in.) high]. The samples were packed to fill the dishes, then weighed. Weights ranged from 49 g to 126 g. Samples were then submitted for analysis. Since the ratio of the portion in the dish to the total weight of each sample was not recorded, the absolute amount of each sample is unknown. Therefore, total radionuclide activity per sample was not determined.

2.4 SAMPLE ANALYSIS

All 92 samples were examined for gamma emitters using a High Resolution Gamma-Ray Spectroscopic Method for soil samples (Oakes et al., 1981). For beta and alpha emitters, destructive radiochemical separation procedures were used. Procedure 2.5 "Radiochemical Method for Determining Plutonium in Soil and Sediments" in ORNL/TM-7212 was followed with minor modifications (Oakes, et al., 1981). Ten of the 92 samples were selected for radiochemical analysis. Six of the ten samples (4DD1, 29DD1, 9W4, 17W2, 39F5, 10G3) were chosen at random, with the remaining four samples (4DD9, 4DD10, 4DD11, and 4DD12) included because of their elevated ^{137}Cs and ^{60}Co concentration.

3. RESULTS

Soil samples were collected from twenty-five core locations. Table 1 contains the identification, drilling depths, and actual locations (in ORNL coordinates) in Columns 1, 2, and 5, respectively. One or more samples were obtained at each core location. Sequentially, samples were collected from top of soil to deep underground. The core identification number represents the sequence in which the sample was taken. For example, the number 1AA1 refers to the first sample collected at core location 1AA. When one segment (46 cm) was subdivided into two, an A or B was put after the sequence number. For example, the number 1AA2A identifies this sample as the top part of the second sample collected at core location 1AA.

The exact depth at which each soil sample was collected was not recorded. Therefore, only total depth drilled at each core location is given in Column 2 of Table 1. A rough estimate can be obtained by dividing the total depth of the core by the number of segments collected per core.

All samples were submitted for gamma spectroscopy analysis, which was performed using a high resolution Ge(Li) detection system. Precision of measurement was $\pm$ 10%. The ^{137}Cs activity in each of the samples is listed in Column 4, Table 1. Four samples (4DD9, D4410, 4DD11, and 4DD12)

Table 1. Core Locations, Depths, and ^{137}Cs Activity

Core #	Total Depth Meters (feet)	Sample Identification	Gamma Activity ^{137}Cs(Bq/g)[d]	Coordinates North	East
1AA	1.8 (6')	1AA1[a]	ND[c]	21801.6	30796.4
		1AA2A[b]	ND		
		1AA2B[b]	ND		
		1AA3	3×10^{-2}		
1DD1	1.5 (5')	1DD1	3.1×10^{-1}	21796.1	30796.1
		1DD2	6.3×10^{-2}		
4DD	7.6 (25')	4DD1	ND	21806.1	30815.9
		4DD2	1.1×10^{-2}		
		4DD3	3.7×10^{-2}		
		4DD4	ND		
		4DD5	3.0×10^{1}		
		4DD6	ND		
		4DD7A	4.1×10^{-1}		
		4DD7B	1.6×10^{-1}		
		4DD8	5.2		
		4DD9	1.0×10^{1}		
		4DD10	2.4×10^{2}		
		4DD11	1.7×10^{3}		
		4DD12	2.8×10^{2}		
9DD	3.0 (10')	9DD1	ND	21806.1	30822.3
		9DD2	ND		
		9DD3	ND		
		9DD4	ND		
		9DD5A	ND		
		9DD5B	ND		
9W	2.7 (9')	9W1	ND	21824.0	30834.3
		9W2	ND		
		9W3	ND		
		9W4	ND		
10G	3.0 (10')	10G1	1.0	21866.4	30845.6
		10G2	2.2×10^{-1}		
		10G3	2.0×10^{-1}		
		10G4	2.7×10^{-1}		
		10G5	9.6×10^{-1}		
17W	1.5 (5')	17W1	ND	21824.0	30848.5
		17W2	ND		

Table 1. (Continued)

Core #	Total Depth Meters (feet)	Sample Identification	Gamma Activity ^{137}Cs(Bq/g)[d]	Coordinates North	East
18O	1.8 (6')	18O1A	ND	21850.2	30851.8
		18O1B	ND		
		18O2	ND		
		18O3	ND		
19CC	2.7 (9')	19CC1A	2.6×10^{-2}	21799.4	30848.1
		19CC1B	ND		
		19CC2	ND		
		19CC3	ND		
		19CC4	ND		
20G	4.3 (14')	20G1	5.6×10^{-2}	21879.9	30853.2
		20G2	1.9×10^{-2}		
		20G3A	6.7×10^{-1}		
		20G3B	3.1×10^{-1}		
		20G4	4.4×10^{-1}		
22W	1.2 (4')	22W1	ND	21824.0	30868.9
		22W2	ND		
29AA	2.7 (9')	29AA1	ND	21805.1	30883.9
		29AA2	ND		
		29AA3	ND		
29DD	1.2 (4')	29DD1	8.9×10^{-1}	21800.1	30887.9
29F	3.0 (10')	29F1	ND	21879.7	30913.9
		29F2	ND		
		29F3	ND		
		29F4A	3.3×10^{-2}		
		29F4B	2.0×10^{-1}		
39AA	2.7 (9')	39AA1A	1.1×10^{-1}	21798.0	30908.3
		39AA1B	ND		
		39AA2	3.0×10^{-2}		
		39AA3	ND		
		39AA4	ND		
39F	4.0 (13')	39F1	ND	21879.7	30940.7
		39F2	ND		
		39F3	5.6×10^{-2}		
		39F4	6.3		
		39F5	4.4×10^{-2}		
47	1.5 (5')	47P1	7.0×10^{-1}	21846.9	30948.6
		47P2	ND		

Table 1. (Continued)

Core #	Total Depth Meters (feet)	Sample Identification	Gamma Activity $^{137}Cs(Bq/g)^d$	Coordinates North	East
49G	1.8 (6')	49G1	$4.1x10^{-2}$	21867.1	30953.5
		49G2A	ND		
		49G2B	ND		
49M	1.5 (5')	49M1	ND	21856.8	30953.5
		49M2	ND		
49W	1.5 (5')	49W1	ND	21824.0	30967.5
		49W2	ND		
49Z	2.1 (7')	49Z1	$4.1x10^{-2}$	21814.1	30953.5
		49Z2A	ND		
		49Z2B	ND		
59M	1.5 (5')	59M1	ND	21856.8	30986.3
		59M2	ND		
59V	1.8 (6')	59V1A	$2.6x10^{-2}$	21827.2	30986.3
		59V1B	$2.2x10^{-2}$		
		59V2	ND		
		59V3	ND		
66T	0.6 (2')	66T1	$2.9x10^{-1}$	21833.8	30997.3
67M	1.5 (5')	67M1	$2.8x10^{-1}$	21856.8	31026.5
		67M2	$2.6x10^{-2}$		

[a]Numerical number immediately following core identification represents sequence of soil sample collected, (such as 1 after 1AA means first 46 cm segment taken from core 1AA).

[b]A and B here indicate a 46 cm soil segment was subdivided into two samples.

[c]ND means levels below the detection limit, approximately 0.02 Bq/g (0.5 pCi/g).

[d]1 Bq = 27 pCi

Note: The precision of CS-137 measurement is approximately in the range of $\pm$ 10%.

contained 90% of the total ^{137}Cs activity. These four samples were also the only samples that showed detectable gamma activities from ^{60}Co. Cobalt activities were: 4DD9 [3.3×10^{-2} Bq/g (0.9 pCi/g)], 4DD10 [6.2×10^{-1} Bq/g (1.6×10^{1} pCi/g)], 4DD11 [8.5 Bq/g (2.3×10^{2} pCi/g)] and 4DD12 [1.7 Bq/g (4.6×10^{1} pCi/g)]. Sample 4DD12 also contained ^{134}Cs, ^{154}Eu, and ^{241}Am. Samples 4DD11 and 39F4 probably contained ^{241}Am. Naturally occurring radioelements appeared to be distributed normally. The maximum ^{226}Ra found was 6×10^{-2} Bq/g (1.7pCi/g).

Since four samples indicated high gamma activities, these four samples along with six other randomly chosen samples were submitted for beta- and alpha-emitter determination. Results from the destructive radiochemical separation are shown in Table 2. A list from the beta activity from ^{90}Sr is given in Column 4. A list of the alpha activities of the individual nuclides, ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Am are given in Columns 5-8. Column 9 represents gross alpha activities. The precision of these measurements was $\pm$20%. Gamma activities of ^{137}Cs and ^{60}Co are given in Columns 2 and 3 for comparison.

In Figures 9, 10, and 11 radioactivities of different emitters are plotted to compare the different types of activity using data from the ten samples selected for radiochemical analysis. Figure 9 is a comparison of the gamma activities of ^{137}Cs vs ^{60}Co. Figure 10 is a comparison of the gamma activity of ^{137}Cs vs the alpha activity of ^{235}U. Figure 11 is a comparison of the gamma activity of ^{137}Cs vs the beta activity of ^{90}Sr. There was a significant positive correlation for ^{137}Cs and ^{60}Co ($r=.996$, $p<.01$), ^{90}Sr ($r=.860$, $p<.01$), ^{235}U ($r=0.944$, $p<.01$) ^{238}U ($r=0.967$, $p<.01$), and gross alpha activity ($r=.991$, $p<.01$). It is clear that a sample which contained higher ^{137}Cs activity also contained higher activity from ^{60}Co, ^{90}Sr, ^{235}U, ^{238}U and gross alpha. Samples found to contain activity below the detectable limit (0.02Bq/g) of ^{137}Cs also showed lower beta and/or alpha contamination. This correlation suggests the occurrence of beta and alpha contaminations in conjunction with gamma activity.

Although beta and alpha measurements were done on only 10 samples, from the correlation found in these 10 samples, and the level of ^{137}Cs activity

Table 2. Gamma Activity[a] of ^{137}Cs and ^{60}Co, Beta Activity of ^{90}Sr, and Alpha Activity of of Selected Samples

Identification Sample	^{137}Cs Bq/g[b]	^{60}Co Bq/g	^{90}Sr Bq/g	^{235}U Bq/g	^{238}U Bq/g	^{239}Pu Bq/g	^{241}Am Bq/g	Gross Alpha Bq/g
4DD1	ND[c]	ND	<9.0	1.5×10^{-3}	2.5×10^{-2}	ND	ND	<0.4
4DD9	1.0×10^{1}	3.3×10^{-2}	8.6×10^{1}	1.6×10^{-3}	2.4×10^{-2}	ND	ND	<0.6
4DD10	2.4×10^{2}	6.2×10^{-1}	1.5×10^{2}	2.4×10^{-3}	5.8×10^{-2}	ND	ND	<1.0
4DD11	1.7×10^{3}	8.5×10^{0}	2.3×10^{2}	7.5×10^{-3}	2.1×10^{-1}	2.8×10^{1}	5.2	3.3×10^{1}
4DD12	2.8×10^{2}	1.7×10^{0}	8.0×10^{1}	2.8×10^{-3}	5.0×10^{-2}	ND	ND	<4.0
29DD1	8.9×10^{-1}	ND	2.5×10^{1}	2.6×10^{-3}	5.3×10^{-2}	ND	ND	<0.6
9W4	ND	ND	$<2.0\times10^{0}$	1.4×10^{-3}	2.9×10^{-2}	ND	ND	<0.7
39F5	4.4×10^{-2}	ND	1.6×10^{1}	3.1×10^{-3}	6.3×10^{-2}	ND	ND	<0.7
17W2	ND	ND	$<8\times10^{0}$	1.0×10^{-3}	1.7×10^{-2}	ND	ND	<0.7
10G3	2.0×10^{-1}	ND	<9.0	1.4×10^{-3}	3.2×10^{-2}	ND	ND	<0.5

[a]Corresponding gamma activities were supplied for easy comparison.

[b]1Bq = 27 pCi

[c]ND = nondetectable.

in the remaining samples, it is apparent that most of the contamination observed in this study appeared in only one very deep soil core (4DD).

4. DISCUSSION

From the data shown in Tables 1 and 2, it is clear that only samples obtained from the deep part of 4DD contained high levels of activity. Core 4DD was taken at the southwest part of the survey site which is at a lower elevation than the other areas. The core 4DD location was approximately 10 m (33 ft) south of the reactor fuel handling canal and 1 m (3.3 ft) east of two radioactive waste transfer lines. The canal or the waste lines could have been potential sources of the detected contamination. Significantly, the fuel handling canal is still highly contaminated with ^{137}Cs and ^{90}Sr (Boing, 1981, Peretz and Alexander, 1982). A survey of the integrity of the canal and waste lines has not been performed and may be warranted.

The 4DD core penetrated to a 7.6 m (25 ft) depth and was the only core that was drilled to that depth. As predicted in the ERC report (ERC, 1979) groundwater was encountered at that depth. A layer of shale was penetrated between 3 m (10 ft) and 4.6 m (15 ft) and the drilling was continued down to 7.6 m (25 ft). Groundwater appeared between 5.5 m (18 ft) and 6 m (20 ft) and initially flowing water rapidly filled the hole to the surface during the drilling. Eventually the water level subsided to the original groundwater table. It is not unreasonable to assume that the relatively high level of radionuclides detected could have been carried by underground water. Unfortunately, there is no available information on radionuclide content of the groundwater in this area. Because of the movement of groundwater, there is no reason to believe the source of the activity necessarily originated in the immediate vicinity of the find and, in fact, could have come from a long distance away. Information obtained by drilling deep into the groundwater around this area would be helpful in determining the degree of contamination, the distance it has traveled, and possibly its source.

Since the groundwater under Building 3505 seems to be a possible source of contamination, any groundwater encountered in future drillings should be collected and tested.

Since activities presented in this report are given only per gram of dry sample, and since the density of each sample was not determined and may vary significantly, total activity per segment or per sample was not calculated. Therefore, assumptions about the total activity in the area are not warranted. In addition, water contained in the samples was often lost during collection so that water soluble activity could have been lost and drying at 105^{o} C (221^{o} F) could have resulted in the loss of volatile activity. Consequently, activities reported here could be underestimated significantly, especially for those samples collected in the groundwater region.

5. CONCLUSION

The high activity of ^{137}Cs in core 4DD compared to the activities in all other cores suggests that this core is unique. However, with the current data there is no way of knowing whether the activity is from an active current leak or is residue from an old leak. Only additional investigation in the area of the 4DD core will determine the degree of contamination, the distance it has traveled, and the sources. The fact that cores adjacent to core 4DD were driven to refusal at a much shallower depth may represent some practical drilling difficulty in future investigations.

Because core 4DD was located on the southwest side of the Metal Recovery Facility, which is at a lower elevation than the rest of the site, leakage from underneath the facility could drain to this spot. On the other hand, the source of the radionuclide contamination could be far away. Only additional drilling deep into the underground water at other sites around this area can provide more definitive information. Although the source of contamination could have originated elsewhere, it may still be worthwhile investigating the integrities of two potential local sources: the canal and the fission products processing line, even though these two structures will be decommissioned in the D & D procedure.

Since no soil samples were collected immediately under the building structure, it is not known whether the soil under this building is contaminated. This also should be investigated.

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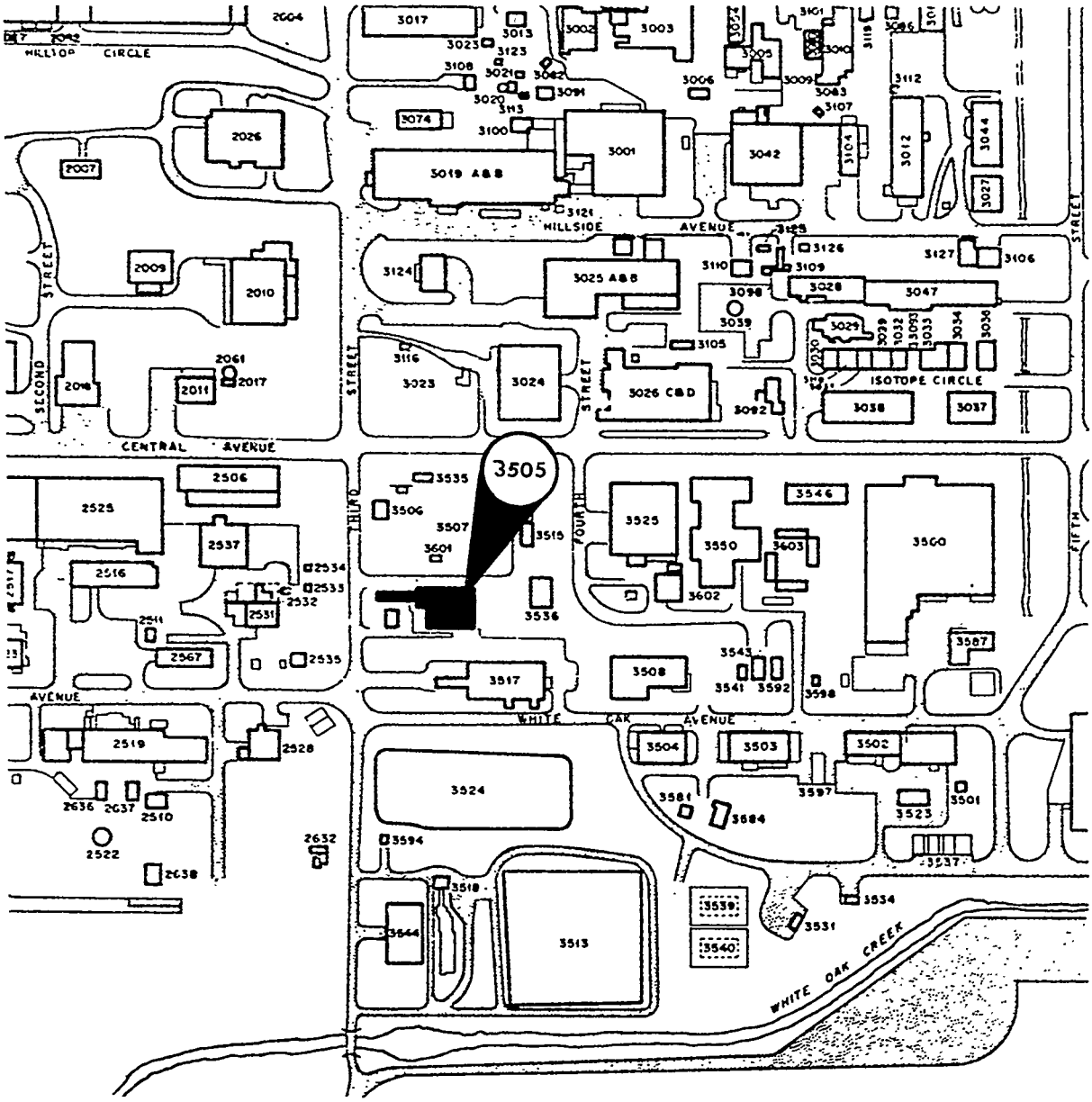


Figure 1. A portion of ORNL X-10 complex.

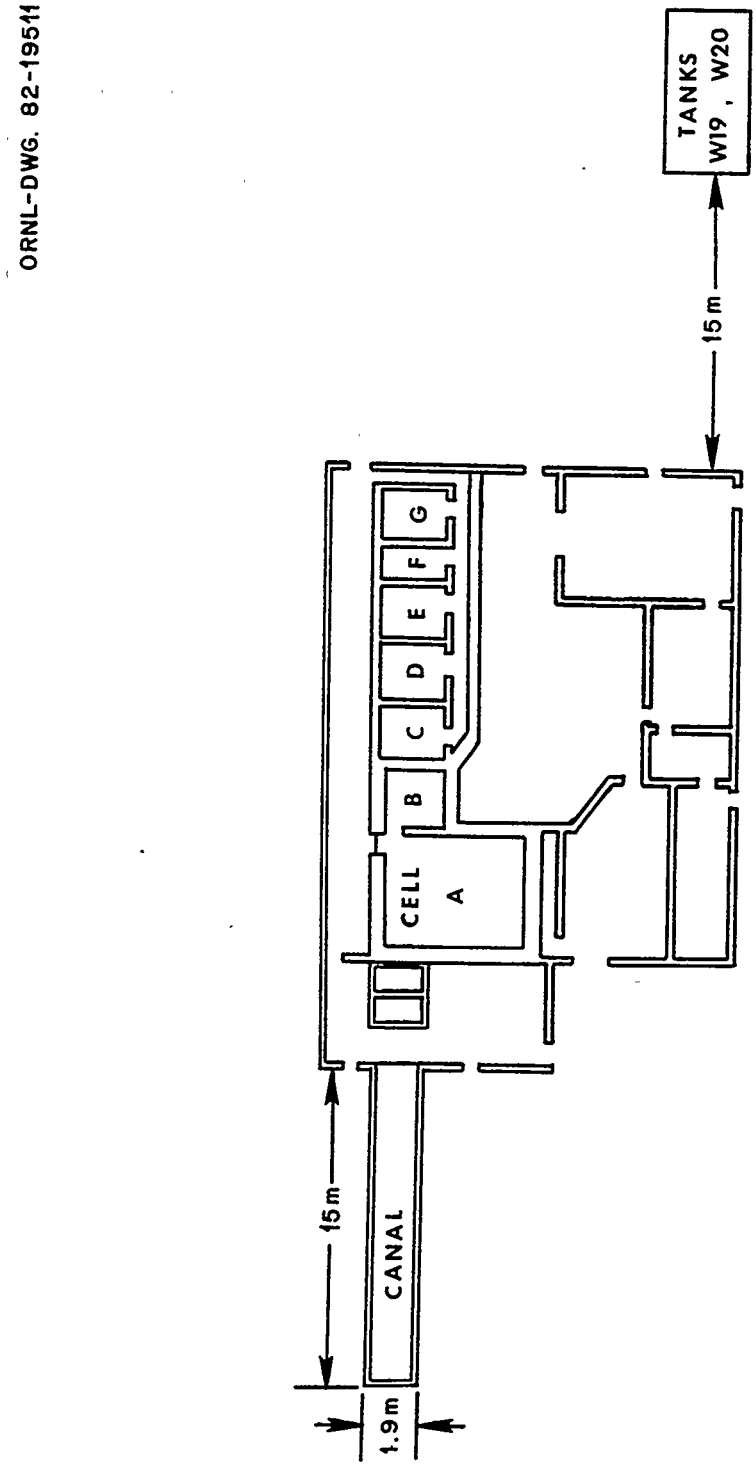


Figure 2. Building 3505 Floor Plan

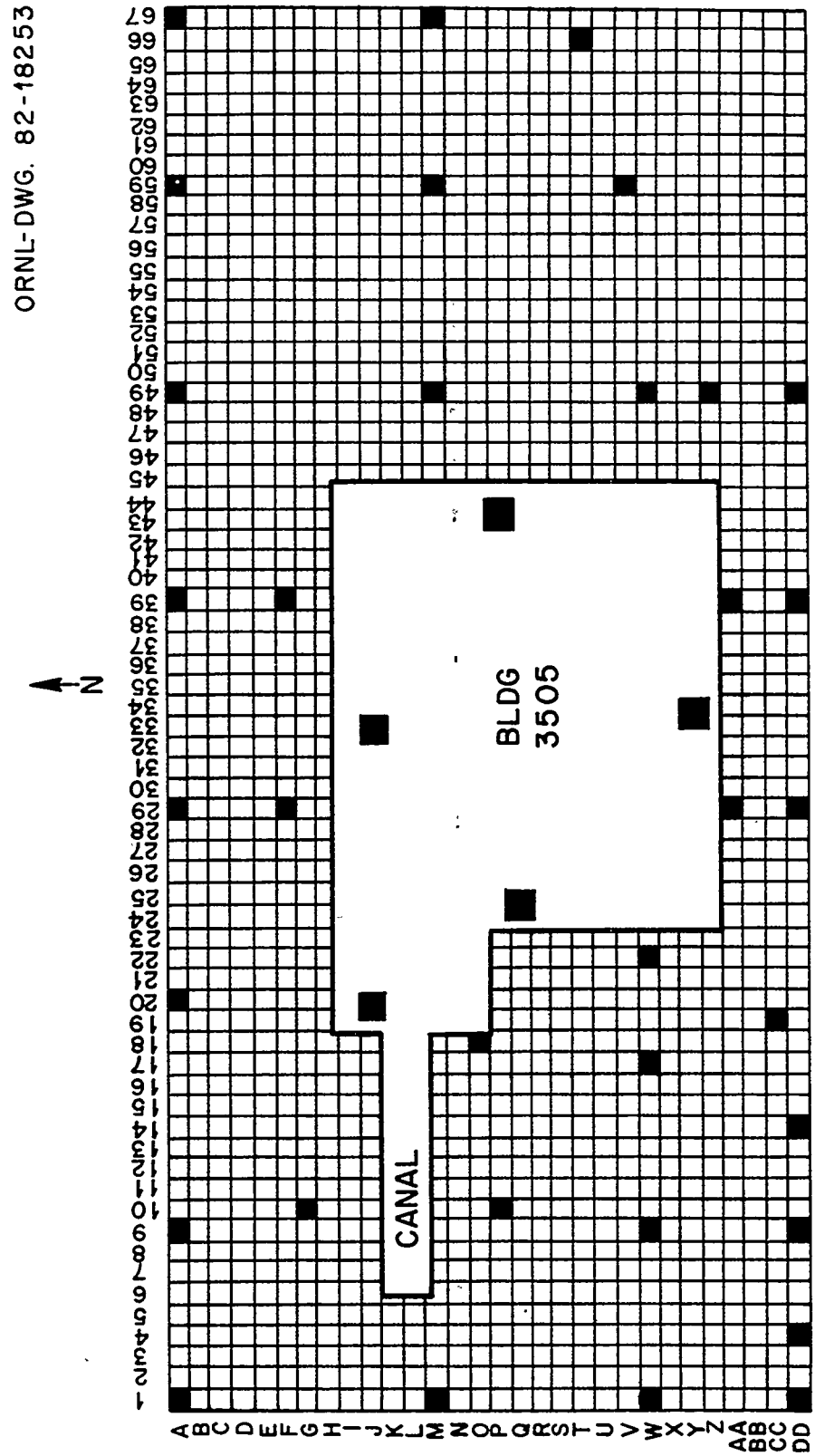


Figure 3. ERC Survey Plan Grid layouts of soil core locations.

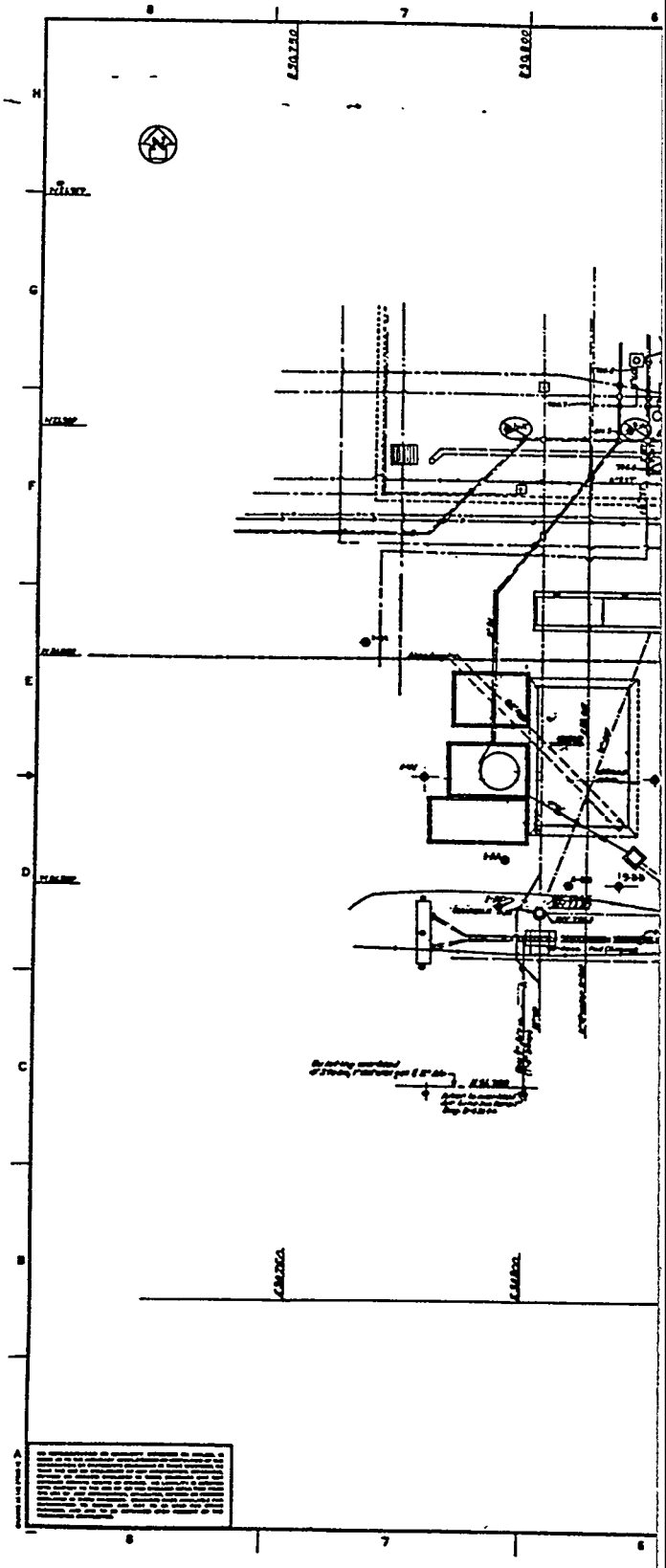
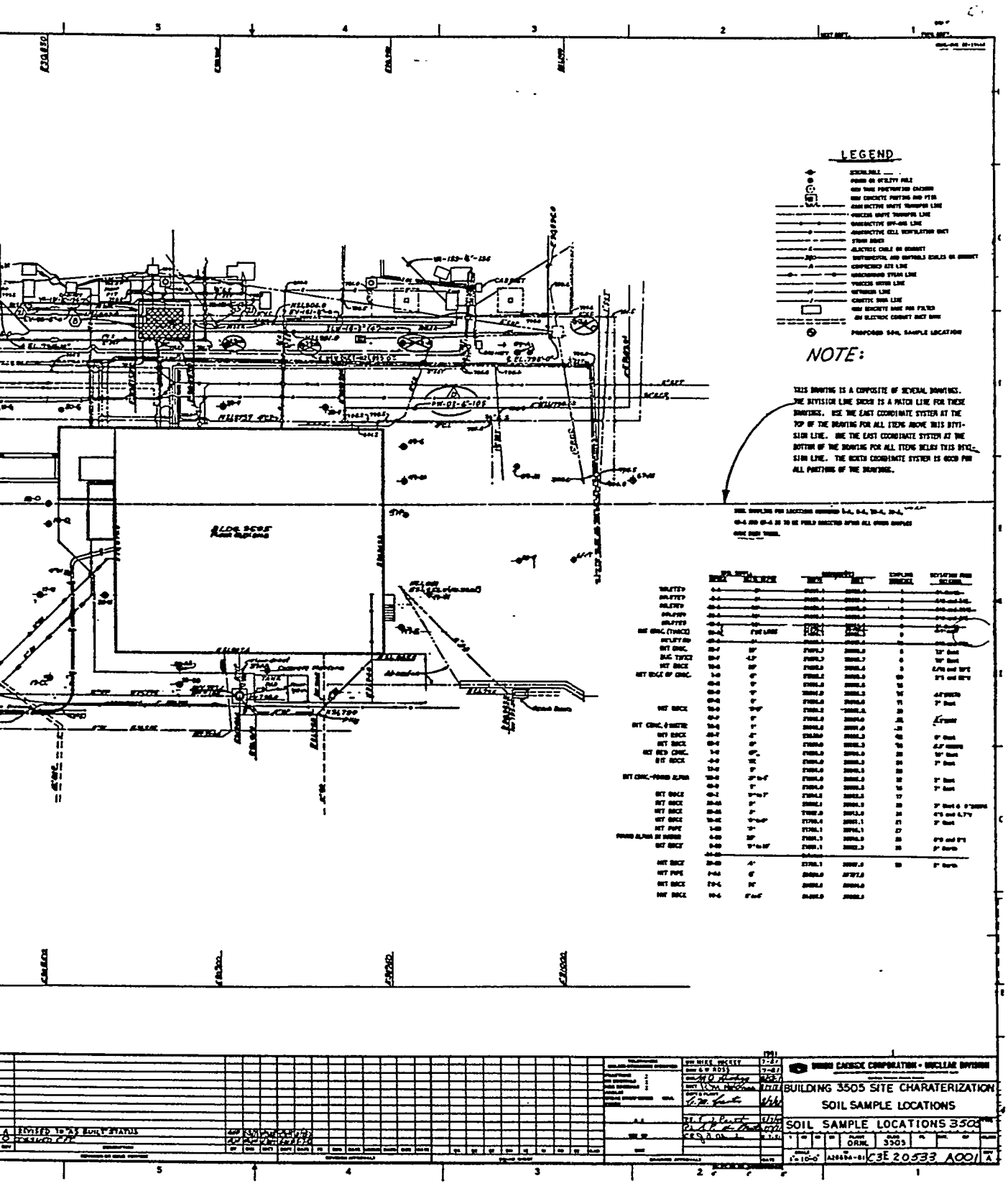


Figure 4. N



p of 3505 and vicinity marked with actual drill locations.

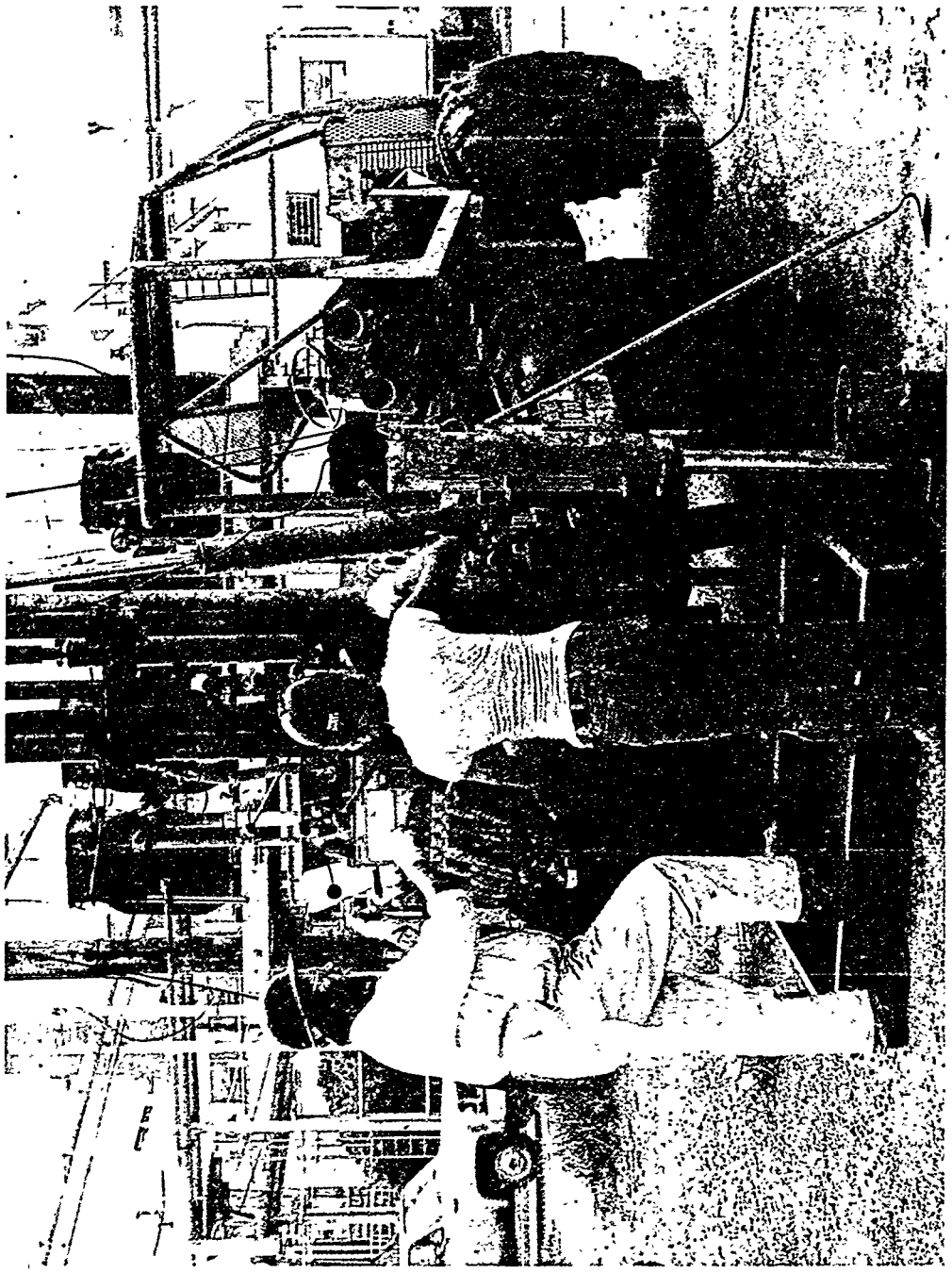


Figure 5. Drilling auger and coring tube

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Figure 6. Core drilling in progress.

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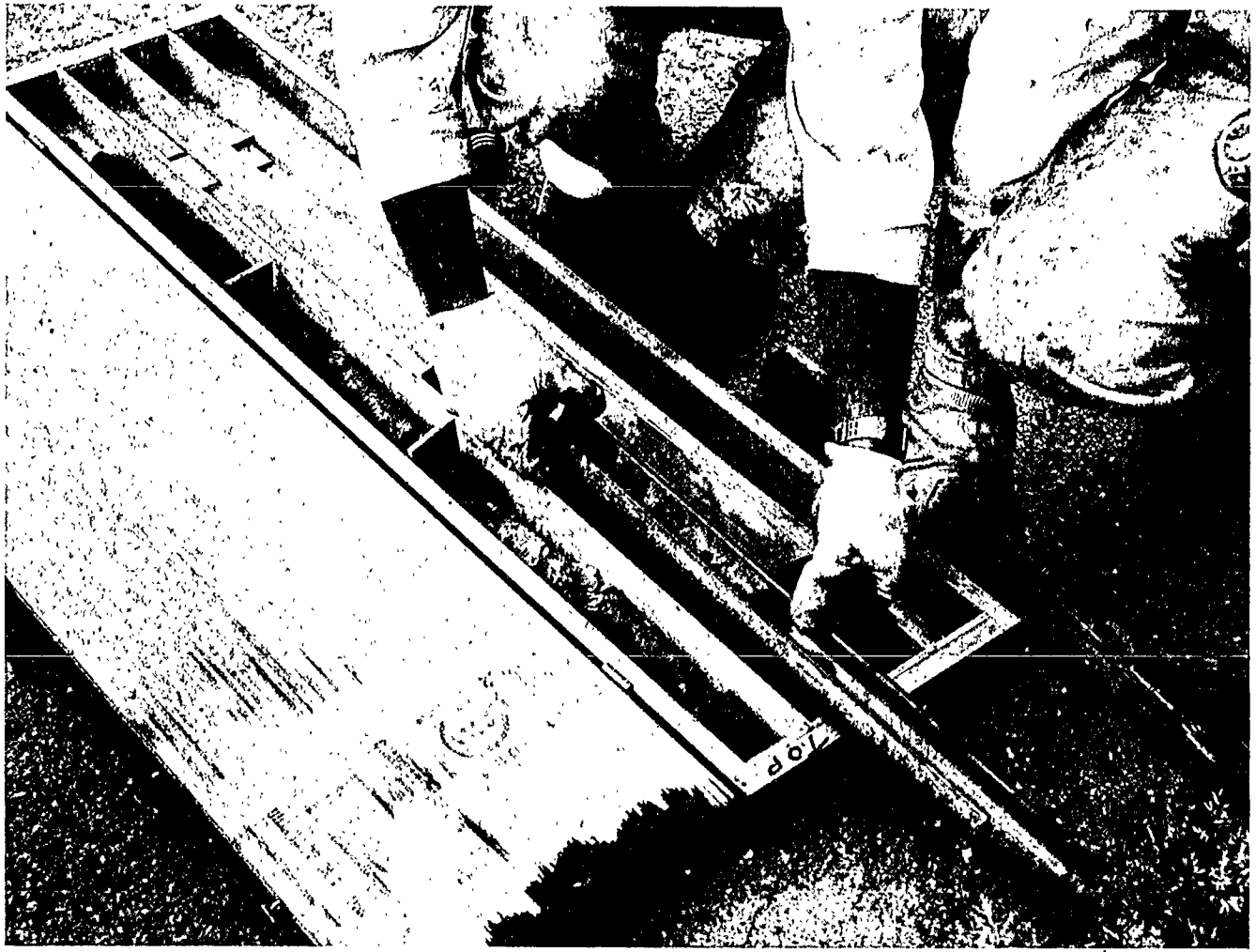

Figure 7. Soil segment placement into wooden box.

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Figure 8. A health physicist checking for external radiation levels

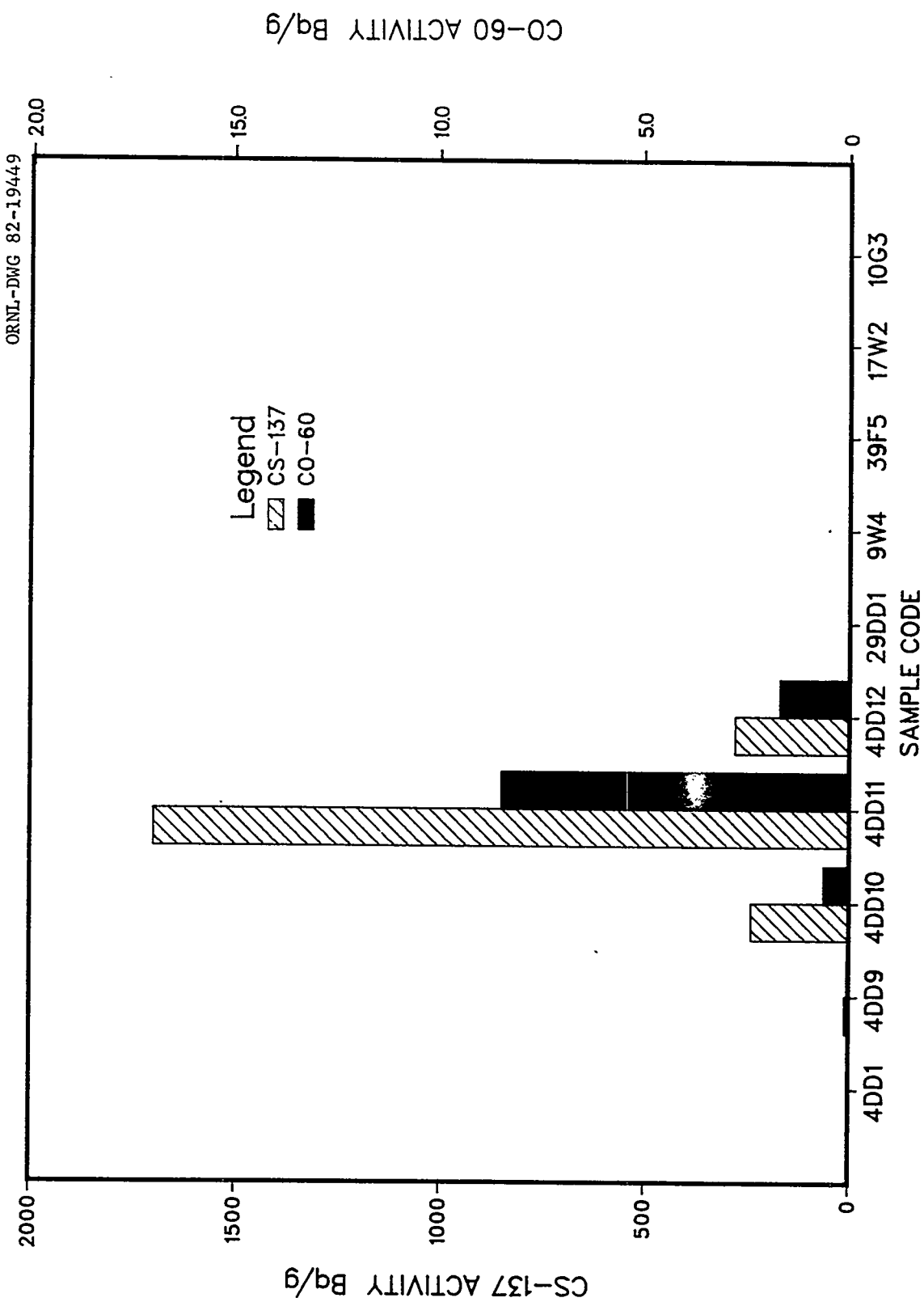

Figure 9. Gamma activities of ^{137}Cs and ^{60}Co in selected samples

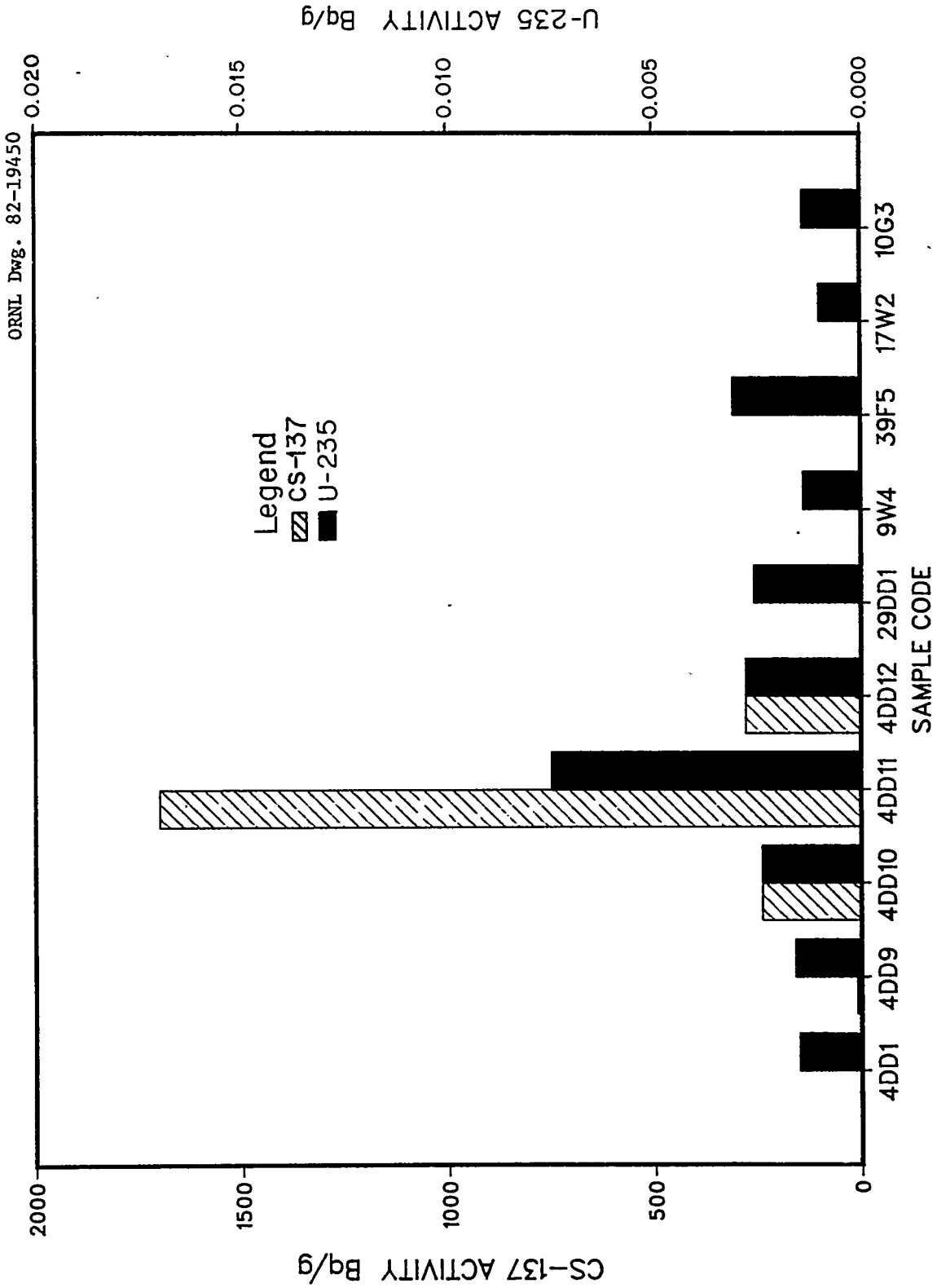

Figure 10. Gamma activities of ^{137}Cs and alpha activities of ^{235}U in selected samples

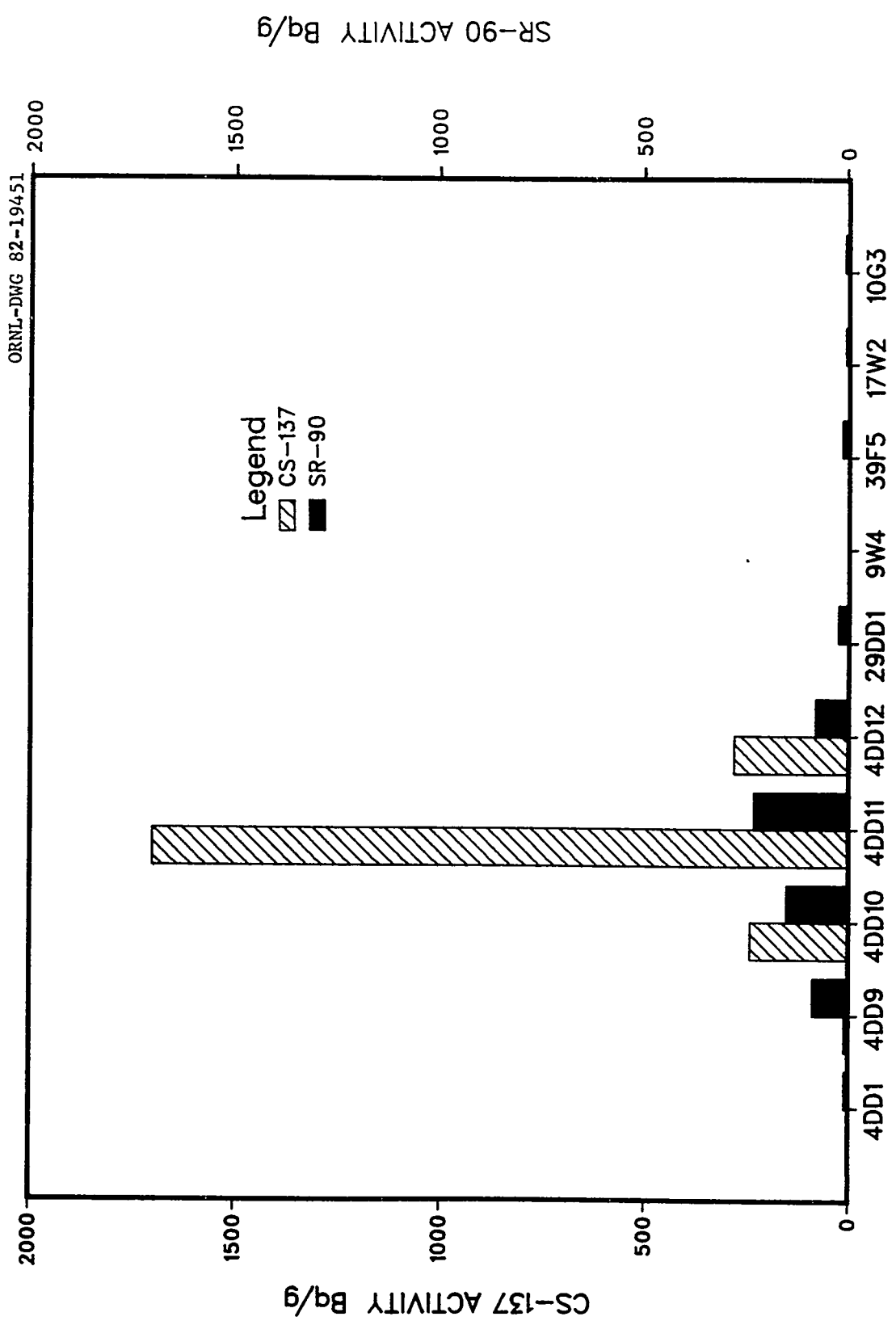

Figure 11. Gamma activities of ^{137}Cs and beta activities of ^{90}Sr in selected samples

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